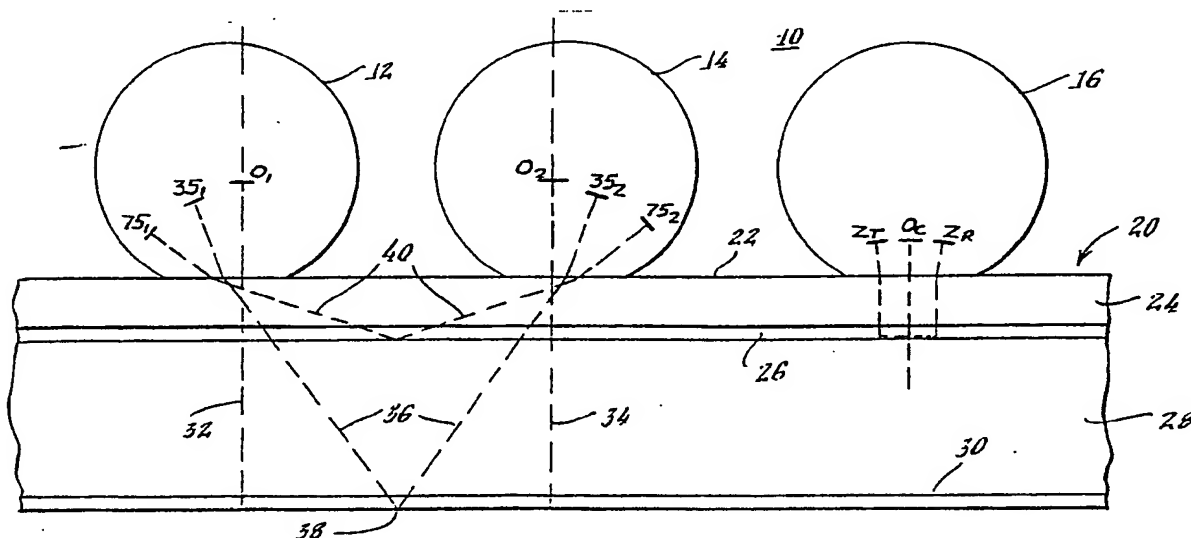




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US82/00568 <b>(22) International Filing Date:</b> 3 May 1982 (03.05.82)  <b>(31) Priority Application Number:</b> 260,606 <b>(32) Priority Date:</b> 6 May 1981 (06.05.81) <b>(33) Priority Country:</b> US  <b>(71) Applicant:</b> AUTOMATION INDUSTRIES, INC. [US/US]; 500 West Putman Avenue, Greenwich, CT 06830 (US).  <b>(72) Inventor:</b> MARTENS, George, D. ; R.F.D. 1, Clearview Drive, New Milford, CT 06776 (US).		<b>(74) Agent:</b> BRAMBLETT, Garold, E., Jr.; 460 Summer Street, Stamford, CT 06901 (US).  <b>(81) Designated States:</b> AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), HU, JP, LU (European patent), NL (European patent), SE (European patent).  <b>Published</b> <i>With international search report.</i> <i>With amended claims.</i>

**(54) Title:** AN ULTRASONIC RAIL TESTING METHOD AND SYSTEM**(57) Abstract**

A method and apparatus for ultrasonically inspecting railroad rails (20) utilizing a plurality of ultrasonic roller search units (12, 14, 16). Each search unit is a liquid filled elastomeric tire containing one or more ultrasonic transducers (35, 75, O, Z). The liquid couples the ultrasound between the rail and each transducer. The spaced wheels are in rolling contact with the rails being inspected. The system utilizes a plurality of differently oriented beams (32, 34, 36, 40, 50) of ultrasonic energy from the transducers which are pulsed at different times for probing various regions of the rails being inspected. The transducers receive through transmission or pulse echo ultrasonic energy from the workpiece and use such information to determine the location and nature of defects in the rail.

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## AN ULTRASONIC RAIL TESTING METHOD AND SYSTEM

Technical Field

The field of this invention is the automatic ultrasonic testing of railroad rails in track.

Background Art

5 This invention relates to ultrasonic rail testing methods and apparatus and, more particularly, to the orientation of a plurality of ultrasonic transducers. The transducers are mounted in liquid filled roller search units which are relatively conventional. They take the form of  
10 a plurality of spaced wheels in rolling contact with the rails being inspected. The transducers establish through transmission and pulse echo paths for probing, and providing flaw information from, different regions of the rails being inspected.

15 The ultrasonic inspection of rails utilizing ultrasonic pulse echo reflection techniques is well known and widely used. One such system, disclosed in U. S. Patent 3,415,110 and assigned to the assignee of the present invention, utilizes three transducers in each of two spaced  
20 wheels of a rail search unit in rolling contact with the rails being inspected. The wheels are provided with



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suitable couplant means for coupling the radiation emitted or received by the transducers to and from the rails. Such a system has been useful in reliably and quickly detecting defects in rails.

5 In U. S. Patent 4,174,636 leading and trailing wheel means are provided with a plurality of transducers, namely 12 in number, oriented to probe the rail for various types of defects. Among these transducers are one group of three which are aimed forwardly and are pulsed together to  
10 produce a diverging beam. This beam fills the entire cross-section of the rail head in front of the leading wheel. Another group includes three transducers which are rearward looking and perform the same function at the rear of the trailing wheel. Side looking transducers are also provided  
15 for beaming ultrasonic radiation to the lower corners of the gage and field sides of the rail head. They are monitored for loss of amplitude of reflected energy, indicating the presence of a vertical split head defect. One of the problems with this approach is that the ultrasonic radiation  
20 of the side looking transducers could be reflected off a defect to the lower corner of the rail and back to the transducer without indicating that a fault exists. Also, precision vertical and lateral positioning of the transducers over the rail is required and would be difficult to achieve  
25 in worn rails. These and other difficulties, when primarily utilizing the pulse echo technique of ultrasonic rail testing, render defect identification and processing difficult.

### Disclosure of Invention

It is an object of this invention to provide new  
30 and improved method and apparatus for ultrasonic rail inspection in order to alleviate some of the problems in detecting and identifying certain types of rail defects.



## 3.

Another object of this invention is to provide new and improved method and apparatus for an ultrasonic rail inspection system which is more sensitive and capable of detecting a wider variety of defects with greater accuracy than previous systems.

Still another object of this invention is to provide new and improved method and apparatus for the ultrasonic inspection of rails which provides for both primary and redundant information which may be utilized in characterizing the type and size of the various defects in the rail.

In carrying out this invention in one illustrative embodiment, method and apparatus are provided for ultrasonically inspecting railroad rails utilizing a plurality of ultrasonic transducers mounted in a plurality of spaced wheels. The wheels are in rolling contact with the rail being inspected. First and second aligned groups, each including a plurality of transducers in one of the two spaced wheels, are oriented and aimed at each other. The first group is aimed downwardly and forwardly from the trailing wheel. The second group is aimed downwardly and rearwardly from the leading wheel. Ultrasonic radiation from at least two transducers of one group is received by the second group after intermediate reflections from opposite sides of the head of the rail.

Other transducers mounted in the two spaced wheels face each other. One transducer faces downwardly and rearwardly from the leading wheel and the other transducer faces downwardly and forwardly from the trailing wheel. Ultrasonic radiation is thereby directed between transducers in a through transmission mode after reflection from the bottom of the rail. The latter transducers are aimed at a much more acute angle to the vertical than the angle formed by the groups of transducers.

Another transducer is positioned in each of the



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two spaced wheels aimed perpendicular to the top surface of the rail for reflection from the bottom of the rail.

In addition, a third wheel is provided having two transducers which are aimed at each other through the rail head. Ultrasonic radiation from one of the transducers is transmitted to the other after two reflections from opposite sides of the rail head, thereby taking a Z path through the rail head. -A focused transducer is also provided in the third wheel which is vertically aimed at the center of the rail.

In all, up to twelve ultrasonic channels are provided. The rail under inspection is flooded with ultrasonic energy and the channels provide flaw detection information. (As used herein, the term "channel" refers to a receiving transducer and the data processing functions associated with that transducer.) All but two of the ultrasonic channels are operated in a through transmission mode. Total loss of signal in such a channel would indicate either a problem with the equipment or a defect in the rail. This type of operation is, in many cases, more advantageous than the pulse echo technique alone. For example, it is "fail safe", as explained more fully below. Furthermore, pulse echoes will also be received when defects occur in a through transmission path, thereby providing a double check and further information to positively identify or characterize defects in the rail which in the past have been difficult to detect.

#### Brief Description of the Drawings

The invention, together with further aspects, advantages and features thereto will be more clearly understood, from the following description taken in conjunction with the accompanying drawings.



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FIGURE 1 is a diagrammatic top view of a rail, illustrating the distribution and orientation of a plurality of ultrasonic transducers in accordance with an illustrative embodiment of the present invention.

5       FIGURE 2 is a diagrammatic side view of the rail and transducers shown in FIGURE 1 and showing the wheels containing the transducers.

FIGURE 3 is a cross-section of a rail illustrating the transmission and reception paths of two of the transducers shown in FIGURE 1.

FIGURE 4 is a cross-sectional view of a rail illustrating a focused zero degree transducer and the radiation emitted from the transducer to the interior of a rail.

FIGURE 5 is a chart of flaw information indicating how the type of flaw is deduced by indications from the various transducers illustrated in FIGURES 1 and 2.

FIGURE 6 is a timing chart which is merely illustrative of one manner in which the transducer array illustrated in FIGURES 1 and 2 may be pulsed and gated to detect flaws in the rail being tested.

#### Best Mode for Carrying Out the Invention

The present invention is directed to method and apparatus for rail inspection and resides in the orientation and operation of a plurality of transducers mounted in spaced wheels of a search unit which is in rolling contact with the rail being inspected. The wheels are elastomeric tires filled with an ultrasonic coupling liquid. Since the basic structure of the rail search unit is conventional and forms no part of this invention, it will not be further discussed here in order to simplify the description. The electronic processing which is utilized for evaluating the information received from the rail search unit is also not a part of the present invention. Copending application



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Serial No. \_\_\_\_\_ filed \_\_\_\_\_ by Frank X. Linder and Ronald M. Keenan and assigned to the same assignee as the present application, illustrates one electronic processing system which may be utilized for evaluating the signals received from a rail search unit such as the one described here. The disclosure of that application is incorporated herein by reference.

As employed herein, the term "transmission mode" means that an ultrasonic transmitting transducer sends energy through the rail to a receiving transducer, with or without an intermediate reflection. The term "pulse echo" refers to that mode of operation wherein a transducer receives ultrasonic echoes from flaws encountered. The pulse echoes may be picked up by the transducer emitting the radiation or by another transducer in the path of the signals. In another mode, sound striking the flaw or defect in the material may be reradiated and the ultrasound picked up by still another transducer. This is known as "delta" information.

The mode of transmission or operation will determine the type of processing utilized for evaluating the information received. For example, in the transmission mode, when one transducer is pulsed, the signal should be received by the receiving transducer after a given period of time -- namely, the time it takes for the pulse to travel through the rail. When the transmitted signal is received during such specific time intervals, it is an indication that the rail is free of defects or flaws. If, on the other hand, the signal is not received when it should be, then something is wrong either with the rail or the equipment examining the rail. This creates a "fail safe" situation in that a failure in either the rail or the equipment results in a "reject" signal. In the pulse echo mode, the system is normally geared to look for the receipt of a signal which should not be received except in the presence of a flaw. Thus, equipment failure can result in a false "good" indication.





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Referring now to FIGURES 1 and 2, a rail search unit, referred to generally with the reference character 10, includes three wheels 12, 14 and 16 which are illustrated diagrammatically in FIGURE 2. The wheels 12, 14 and 16 are in rolling contact with a rail 20 being inspected by the rail search unit 10. The positioning of the wheel 16 is not critical and, accordingly, may be located between the wheels 12 and 14, ahead or behind them. It may also be possible to incorporate the functions performed by the wheel 16 in one of the other wheels.

Each of the wheels 12 and 14 has five transducers therein which are capable of both transmitting and receiving ultrasonic energy. Wheel 12 has a  $0^\circ$  transducer  $O_1$  and wheel 14 has a  $0^\circ$  transducer  $O_2$  which are oriented in their respective wheels to transmit and receive pulse echo radiation in the form of longitudinal compression waves. The  $O_1$  and  $O_2$  transducers are oriented directly perpendicular to the top surface 22 of rail 20 such that radiation travels along axes 32 and 34, respectively, through the head 24, web 28, and base 30. From the rail bottom, it is reflected back to its respective transducer. The  $0^\circ$  transducers are extremely useful in locating certain types of head and web defects.

When the  $O_1$  and  $O_2$  transducers are both oriented on the center line of the rail being inspected, they become redundant. In other words, both transducers would see or detect the same defect. One advantageous manner of extending the use of these two transducers is to stagger the  $O_1$  and  $O_2$  transducers on opposite sides of the center line of the rail, but still directed such that the radiation from each goes all the way to the bottom of the rail 30. By so doing, a tracking function will be added. If a reflection is returned from the fillet 26 of the rail, this would indicate that the wheel was not properly positioned with respect to the rail. Additionally, by staggering the transducers,



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more of the rail head is covered by the  $O_1$  and  $O_2$  transducers.

Wheels 12 and 14 also have transducers  $35_1$  and  $35_2$ , respectively, which are oriented and aimed at each other along a through transmission path 36 having an intermediate reflection 38 off the bottom of the rail 20. Transducers  $35_1$  and  $35_2$  are oriented such that the angle of incidence of the radiation entering the rail is  $35^\circ$  with respect to the normal to its top surface. The  $35^\circ$  angle is not critical. The precise angle will depend on the overall system. The requirement, however, is that transducers  $35_1$  and  $35_2$  establish a through transmission path which bounces off the rail bottom.

Each of wheels 12 and 14 contains a group of transducers  $75_{1A}$ ,  $75_{1B}$ ,  $75_{1C}$  and  $75_{2C}$ ,  $75_{2B}$  and  $75_{2A}$ , respectively. These are oriented in alignment across the rail head (See FIG. 1) to provide through transmission path modes between transducers  $75_{1A}$  and  $75_{2A}$  and between  $75_{1C}$  and  $75_{2C}$ . As illustrated in FIGURE 2, this radiation from the  $75_1$  group is coupled in two paths to the  $75_2$  group in wheel 14 by through transmission path 40.

The pulse echo mode is utilized by transducers  $75_{1B}$  and  $75_{2B}$ . As is best illustrated in FIGURE 3, the transducer  $75_{1C}$  transmits radiation which takes two different paths. In a first path 42, radiation is directed from the transducer  $75_{1C}$  through the rail head 24 and is reflected back off the fillet 26 to the transducer  $75_{1C}$ . Other radiation from the transducer  $75_{1C}$  is reflected off the fillet 26, following the path 40 across the head upwardly and horizontally therethrough, to transducer  $75_{2C}$  in wheel 14. The right side of the rail head, as viewed in FIGURE 3, would contain mirror image paths between transducers  $75_{1A}$  and  $75_{2A}$ .

Transducers  $75_{1B}$  and  $75_{2B}$  are directed such that radiation entering the rail at a  $75^\circ$  angle of incidence will



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be propagated down the center of the rail. This radiation would continue down through the web 28, rather than reflecting off the fillet. Thus, it would operate in the pulse echo, rather than the through transmission, mode.

- 5 Here again, it should be pointed out that the angles are not critical. For example  $70^\circ$  or  $73^\circ$  or some other angle may be utilized as long as it provides the two transmission mode paths along each side of the rail head as well as a pulse echo mode path both downwardly and rearwardly and  
10 downwardly and forwardly through the web of the rail.

Five transducers have been described as contained in each wheel 10 and 12. This provides 10 ultrasonic information channels. Only one channel in each wheel operates solely in a pulse echo mode -- namely, that of each of trans-  
15 ducers  $75_{1B}$  and  $75_{2B}$ . These transducers are utilized to find and classify transverse defects and are oriented at a flat angle ( $75^\circ$ ) to provide stronger reflections from the surface of the defect.

Transducers  $75_{1A}$  and  $75_{2A}$ , as well as  $75_{1C}$  and  
20  $75_{2C}$ , are capable of detecting pulse echoes directly from flaws as well as detecting detail fractures using fillet reflections. These transducers also provide through transmission as an additional backup. The diagonally operative receivers indicate vertical split heads or transverse de-  
25 fects by loss of signal from the fillet reflection. Additionally, pulse echo and through transmission tests will indicate shell defects in the head that are not visible to centrally located transducers.

Wheel 16 includes a focused transducer  $O_c$ . The  
30 face 42 of the crystal (FIGURE 4) has a concave shape which focuses the energy transmitted in the head and web area 44. This is primarily to see longitudinal defects -- namely, head and web separations, which might be missed by transducers  $O_1$ ,  $O_2$ . Transducer  $O_c$  floods the area with radiation



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and a reflection of that radiation in a pulse echo mode indicates a defect in that area.

Returning now to FIGURE 1 and to wheel 16, there is shown a transmit-only transducer  $Z_T$  which is aimed at a transducer  $Z_R$  through a "Z" path 50 across the width of the rail head 24. The ultrasonic path begins and ends at approximately the center of the rail. This path includes intermediate reflections 52 and 54 from opposite sides of the rail head. This Z path is primarily for the purpose of detecting vertical split heads. These are difficult to see utilizing other channels due to their particular orientation which either reflects the radiation in the wrong direction or causes them to be completely missed. The  $O_c$  as well as the Z transducers are located closer to the surface of the rail than to the center of the wheel and provide good resolution, virtually filling the head with ultrasound. Transducers  $Z_T$  and  $Z_R$  provide a transmit/receive combination which indicates head defects in substantially any vertical plane. This combination provides great versatility and provides information by signal reduction for identifying a vertical split head. A signal reduction at the end of the rail indicates a slivered end. A loss of signal at rail end indicates that the rail search unit was off the rail. Transverse defects and detail fractures are accompanied by a sharp drop in signal for a very short interval. In a horizontal split head, signal reduction increases as the defect gets closer to the top of the rail.

It should also be noted that the  $O_c$  transducer is located over the Z path 50 between transducers  $Z_T$  and  $Z_R$ . Accordingly, the  $O_c$  transducer may pick up delta information which occurs when a flaw occurs in the Z path. When the  $Z_T$  transducer is pulsed and strikes a flaw in the material, the flaw reradiates the sound which could be picked up by



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the focused  $O_c$  transducer. This provides additional information with respect to the flaw.

Turning now to FIGURE 5, a number of defects which have been discussed are indicated, along with the type of rail flaw information produced by the ultrasonic channels of the present invention. It will be observed that the system provides major, as well as backup, criteria for almost every type of flaw.

In FIGURE 6 a timing chart is provided illustrating one cycle of operation of the various transducers described herein for obtaining information either in the form of positive signals or loss of signals. The cycle is 600 microseconds in length.

As an example, transducers  $75_{1B}$  and  $75_{2B}$  are pulsed at 300  $\mu$ sec. If a signal is received during the interval 50 shown on FIG. 6, the presence of a defect would be indicated. Transducers  $75_{1B}$  and  $75_{2B}$  are looking in opposite directions down the center of the rail and signals received by either in interval 50 would be pulse echo signals caused by the emitted radiation hitting a defect and returning to the transducer.

The  $35^\circ$  transducers are aimed at each other in a through transmission mode via a bottom reflection. Transducer  $35_1$  is pulsed at 0 time and transducer  $35_2$  is pulsed at 300  $\mu$ sec. Transducer  $35_1$  will look for pulse echo signals in time interval 52 while transducer  $35_2$  will look for pulse echo signals in time interval 54. If a pulse echo signal is received at either transducer during these intervals, a defect will be indicated. At the same time, transducer  $35_2$  is looking for loss of signal during time interval 56 while transducer  $35_1$  is looking for loss of signal during time interval 58. These time intervals represent times when signals should be received from the other transducer and the absence of such a signal would be indicative of a



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defect or faulty equipment.

It will be appreciated that the timing chart of FIG. 6 may be considerably varied, depending on the number and type of transducers utilized, as well as on the electronic processing circuitry which is used. This timing chart is representative of the manner by which basic flaw information may be obtained by pulsing certain transducers in a predetermined sequence.

In accordance with the methods and apparatus of the rail inspection system of the present invention, virtually every region of the rail may be inspected. The addition of through transmission monitoring has many advantages over solely pulse echo operation. In the through transmission mode of operation, if the signal disappears from a receiver when it should be there, then either there is a flaw in the rail or the equipment is faulty. In either case, there is a defect signal. However, in the pulse echo mode when the ultrasonic radiation hits the defect at the wrong angle, it may never get back to the transmitter/receiver and the rail may test good where in fact a defect exists. In this rail inspection system only the  $0_c$  and the  $75_{1B}$  and  $75_{2B}$  transducers operate without a through transmission or back reflection monitoring signal.

The Z transmission path included in this system provides a longitudinal, as well as a transverse, component direction in the rail head to detect flaws such as vertical split heads. The ultrasound passes through the critical areas where the vertical split heads begin. Also, since the Z path employs the through transmission mode, flaws will be detected which might be missed using a pulse echo technique.

Since other changes and modifications varied to fit particular operating requirements and environments will be apparent to those skilled in the art, the invention is



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not considered limited to the examples chosen for purposes of illustration. This invention covers all changes and modifications which do not constitute a departure from its true spirit and scope.



14.  
C L A I M S

1. Apparatus for ultrasonically inspecting a rail-  
road rail having head, web, and base portions comprising:

5 a first transducer positioned to direct ultra-  
sonic energy into the head of said rail at approximately  
its centerline and at an angle to the centerline such that  
said energy describes a Z shaped path with reflections off  
each side of said head and exits the head at approximately  
its centerline; and

10 a second transducer positioned to receive ultra-  
sonic energy leaving the rail from said Z path.

2. The apparatus of claim 1 wherein:

a third transducer is positioned to direct ultra-  
sonic energy vertically downwardly into said rail through  
said Z path.

15 3. The apparatus of claim 2 wherein:

the ultrasonic energy from said third transducer  
is focused in the head of said rail.

4. The apparatus of claim 1 or 3 wherein:

20 said transducers are mounted within a search unit  
relatively movable along said rail.

5. The apparatus of claim 4 wherein said search  
unit comprises a liquid filled tire rollable along the head  
of said rail.

25 6. The apparatus of claim 5 wherein said trans-  
ducers are positioned closer to the surface of said rail  
than to the axis of rotation of said tire.





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7. Apparatus for ultrasonically inspecting a railroad rail having head, web, and base portions comprising:

5 a first array of ultrasonic transducers movable along said rail and positioned to direct ultrasonic energy along essentially parallel paths downwardly into said head portion at a first angle to the vertical for reflection off the fillet of said rail;

10 a second array of ultrasonic transducers movable along said rail and longitudinally spaced from said first array to receive said fillet-reflected energy;

15 a third ultrasonic transducer associated with said first array, and movable therewith, positioned to direct ultrasonic energy downwardly into said head, web, and base portions at a second angle to the vertical less than said first angle for reflection off the bottom of said rail; and

20 a fourth ultrasonic transducer associated with said second array, and movable therewith, positioned to receive said bottom-reflected energy.

8. The apparatus of claim 7 further comprising:

25 a fifth transducer positioned to direct ultrasonic energy into the head of said rail at approximately its centerline and at an angle to the centerline such that said energy describes a Z shaped path with reflections off each side of said head and exits the head at substantially its centerline; and

a sixth transducer positioned to receive ultrasonic energy leaving the rail from said Z path.

30 9. The apparatus of claim 7 wherein:

said first array and third transducer are mounted within a first search-unit relatively movable along said rail; and



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said second array and fourth transducer are mounted within a second search unit relatively movable along said rail.

10. The apparatus of claim 8 wherein:

5       said first array and third transducer are mounted within a first search-unit relatively movable along said rail;

          said second array and fourth transducer are mounted within a second search-unit relatively movable  
10 along said rail; and

          said fifth and sixth transducers are mounted within a third search-unit relatively movable along said rail.

11. The apparatus of claim 9 or 10 wherein each of said search units comprises a liquid filled tire roll-  
15 able along the head of said rail.



## AMENDED CLAIMS

(received by the International Bureau on 11 October 1982 (11.10.82))

1. Apparatus for inspecting a railroad rail having head, web, and base portions, including a first transducer positioned to direct ultrasonic energy into the head of the rail at approximately its centerline and at an angle to the centerline such that the energy describes a Z shaped path with reflections off each side of the head and exits the head at approximately its centerline, and a second transducer positioned to receive ultrasonic energy leaving the rail from the Z path characterized by:
- 5 a third transducer being positioned to transmit or receive ultrasonic energy along an axis vertically downward in the rail through said Z path and focused in the head of the rail.
2. The apparatus of claim 1 wherein the first, second, and third transducers are mounted within a search unit relatively movable along the rail.
3. The apparatus of claim 2 wherein said search unit comprises a liquid filled tire rollable along the head of the rail.
4. The apparatus of claim 3 wherein said transducers are positioned closer to the surface of the rail than to the axis of rotation of the tire.
5. Apparatus for inspecting a railroad rail having head, web, and base portions including a first transducer movable along the rail and positioned to direct ultrasonic energy along the length of the rail and along its vertical center plane downwardly into the head portion at a first angle to the vertical to the intersection of the head and web, a second transducer movable along the rail and



longitudinally spaced from the first transducer to receive energy reflected from the head and web intersection, a third transducer associated and movable with the first transducer for directing ultrasonic energy downwardly into the head, web, and base portions at a second angle to the vertical less than the first angle for reflection off the bottom of the rail, and a fourth transducer associated and movable with the second transducer for receiving the bottom-reflected energy, characterized by:

- 10 a fifth transducer associated with, and movable with, the first transducer to direct ultrasonic energy along the length of the rail essentially parallel to, and horizontally spaced from, the path of energy from the first transducer for reflection off the fillet of the rail; and
- 15 a sixth transducer associated with, and movable with, said second transducer to receive said fillet-reflected energy.

6. The apparatus of claim 5 including a seventh transducer positioned to direct ultrasonic energy into the head of the rail at approximately its centerline and at an angle to the centerline such that the energy describes a Z shaped path with reflections off each side of the head and exits the head at substantially its centerline, and an eighth transducer positioned to receive ultrasonic energy leaving the rail from the Z path, further characterized by:

a ninth transducer positioned to transmit or receive ultrasonic energy along an axis vertically downward in the rail through said Z path and focused in the head of said rail.

- 30 7. The apparatus of claim 6 wherein:  
said first, third, and fifth transducers are mounted within a first search-unit relatively movable along said rail;



said second, fourth, and sixth transducers are mounted within a second search-unit relatively movable along said rail; and

said seventh, eighth, and ninth transducers are  
5 mounted within a third search-unit relatively movable along said rail.



EDITORIAL NOTE

The applicant failed to renumber the amended claims in accordance with Section 205 of the Administrative Instructions.

In the absence of any specific indication from the applicant as to the correspondence between original and amended claims, these claims are published as filed and as amended.



Fig. 5.

## ULTRASONIC CHANNELS

DEFECT TYPE	0° <sub>1,2C</sub>	35°	75° <sub>A,C</sub>	75° <sub>B</sub>	Z
COMPOUND LONGITUDINAL-TRANSVERSE DEFECT		O		X	O
DETAIL FRACTURE			X		O
ENGINE BURN FRACTURE	X	X	X	X	O
BOLT HOLE	X	X			
HEAD-WEB SEPARATION	X	X		O	
VERTICAL SPLIT HEAD	O	O	O		X
HORIZONTAL SPLIT HEAD	X	X			O
SPLIT WEB	X	X			
SLIVERED SURFACE	X	O			X
RAIL SEARCH UNIT TRACKING	X				
WELD DEFECT	X	X	X	X	O

## RAIL FLAW INFORMATION

X - MAJOR CRITERIA

O - BACKUP CRITERIA

Fig. 3.

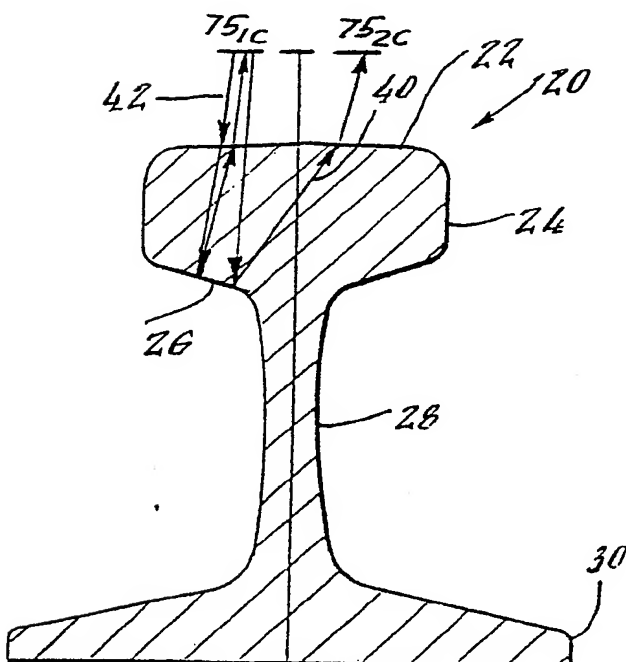
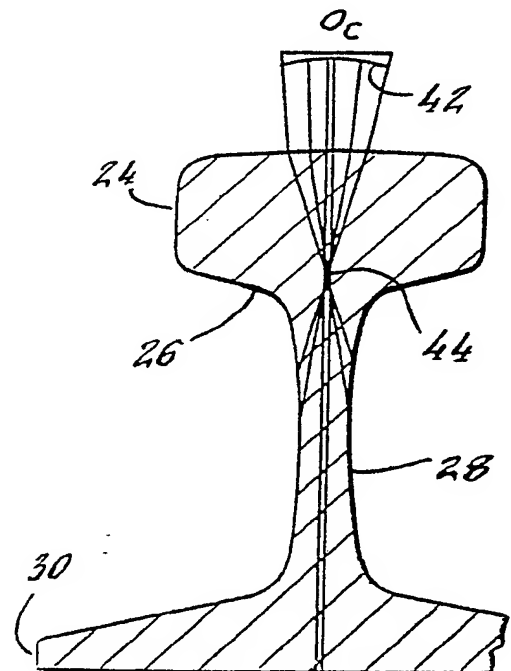
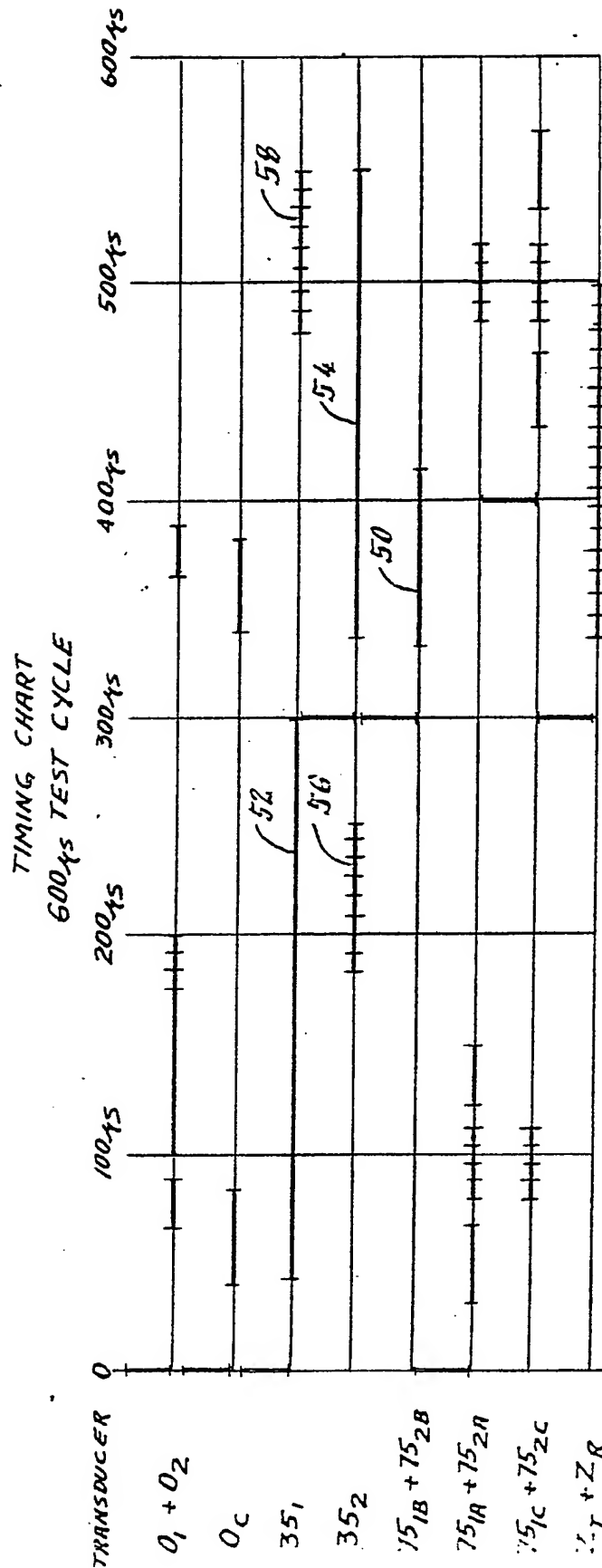


Fig. 4.







CODE

| = PULSE

— = RECEIVE POSITIVE  
SIGNAL

++ = PERCEIVE LOSS  
OF SIGNAL

Fig. 6.



# INTERNATIONAL SEARCH REPORT

International Application No PCT/US 82/00568

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>3</sup> According to International Patent Classification (IPC) or to both National Classification and IPC INT. CL. 3 G01N 29/04 U.S. CL. 73/628																				
<b>II. FIELDS SEARCHED</b> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black;">Minimum Documentation Searched <sup>4</sup></div> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 25%; border-bottom: 1px solid black;">Classification System</th> <th style="border-bottom: 1px solid black;">Classification Symbols</th> </tr> <tr> <td style="padding: 5px;">U.S.</td> <td style="padding: 5px;">73/624, 625, 626, 628, 635, 636, 639, 644</td> </tr> </table> <div style="text-align: center; border-top: 1px solid black; border-bottom: 1px solid black;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>5</sup></div>			Classification System	Classification Symbols	U.S.	73/624, 625, 626, 628, 635, 636, 639, 644														
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<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 10%; border-bottom: 1px solid black;">Category <sup>*</sup></th> <th style="border-bottom: 1px solid black;">Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup></th> <th style="border-bottom: 1px solid black;">Relevant to Claim No. <sup>18</sup></th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;">US, A, 3,962,908, Published 15 June 1976, See Col. 2 Lines 55-58 and Col. 9 Lines 57-60, Joy.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1,4,8,10, 11</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;">US, A, 4,174,636, Published 20 November 1979 See Col. 6 Lines 64-68 and Col. 7 Lines 1-2, Pagano.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">2,3,4,5,7, 9,11</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">X</td> <td style="padding: 5px;">US, A, 3,205,702, Published 14 September 1965, Joy.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">6</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A, 3,415,110, Published 10 December 1968, Cowan.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">1-11</td> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 5px;">A</td> <td style="padding: 5px;">US, A, 3,712,119, Published 23 Jan. 1973, Cross.</td> <td style="text-align: center; vertical-align: top; padding: 5px;">3</td> </tr> </table>			Category <sup>*</sup>	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>	X	US, A, 3,962,908, Published 15 June 1976, See Col. 2 Lines 55-58 and Col. 9 Lines 57-60, Joy.	1,4,8,10, 11	X	US, A, 4,174,636, Published 20 November 1979 See Col. 6 Lines 64-68 and Col. 7 Lines 1-2, Pagano.	2,3,4,5,7, 9,11	X	US, A, 3,205,702, Published 14 September 1965, Joy.	6	A	US, A, 3,415,110, Published 10 December 1968, Cowan.	1-11	A	US, A, 3,712,119, Published 23 Jan. 1973, Cross.	3
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<sup>*</sup> Special categories of cited documents: <sup>15</sup> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed		"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family																		
<b>IV. CERTIFICATION</b> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;">           Date of the Actual Completion of the International Search <sup>2</sup>            27 July 1982         </td> <td style="width: 50%; border-bottom: 1px solid black; padding: 5px;">           Date of Mailing of this International Search Report <sup>3</sup>  <div style="text-align: center; font-size: 1.2em; font-weight: bold;">26 AUG 1982</div> </td> </tr> <tr> <td style="border-bottom: 1px solid black; padding: 5px;">           International Searching Authority <sup>1</sup>            ISA/US         </td> <td style="border-bottom: 1px solid black; padding: 5px;">           Signature of Authorized Officer <sup>20</sup>  <div style="text-align: center;">             Stephen A. Kreitman  </div> </td> </tr> </table>			Date of the Actual Completion of the International Search <sup>2</sup> 27 July 1982	Date of Mailing of this International Search Report <sup>3</sup> <div style="text-align: center; font-size: 1.2em; font-weight: bold;">26 AUG 1982</div>	International Searching Authority <sup>1</sup> ISA/US	Signature of Authorized Officer <sup>20</sup> <div style="text-align: center;">             Stephen A. Kreitman  </div>														
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